Flow and noise from septa nozzles

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Outline of talk:

Introduction

Experimental Facility

Results and Discussion

Summary

Distributed Propulsion

(From Felder, Kim & Brown 2009)

In one (hybrid) version of the concept each passage is driven by an electric fan

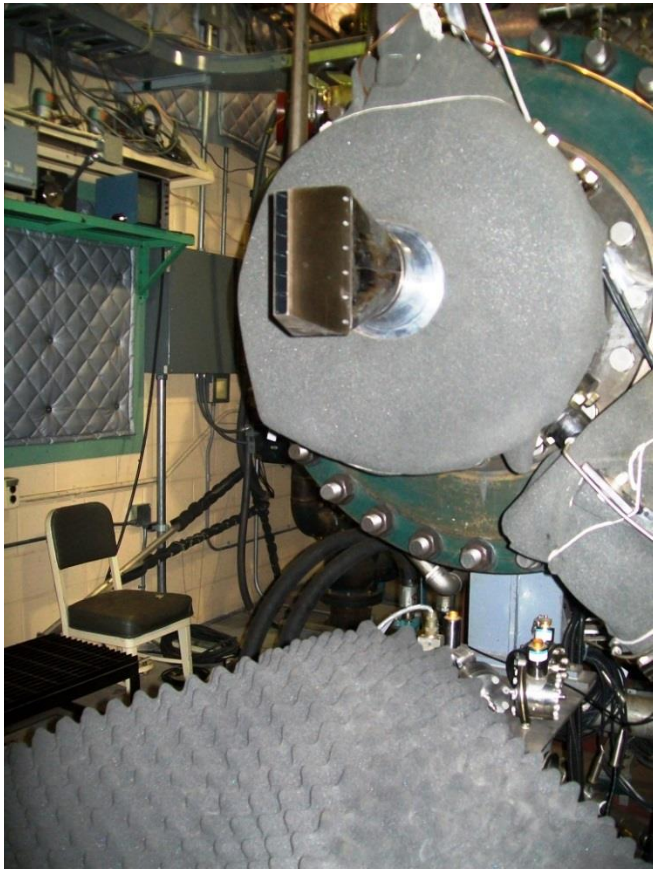
Concern about impact on noise. Will noise be greater than that from a equivalent single jet ?

Scope of the paper:

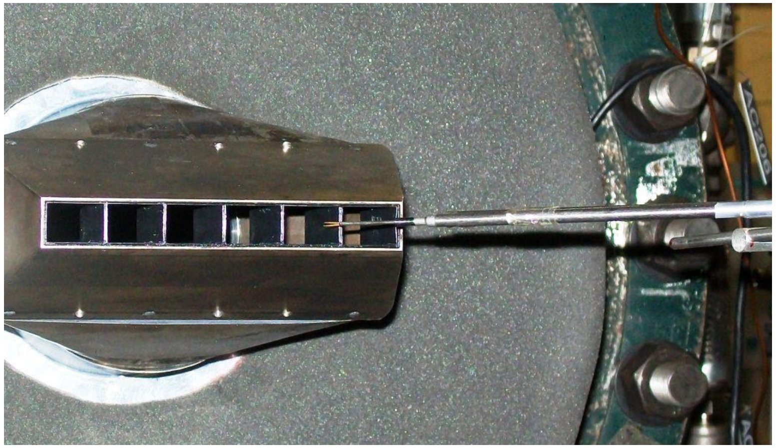
To study some of these aero- and acoustic issues with distributed propulsion, experiments have been conducted at NASA GRC

This paper presents results of a smaller-scale fundamental experiment on the problem

Experimental Facility



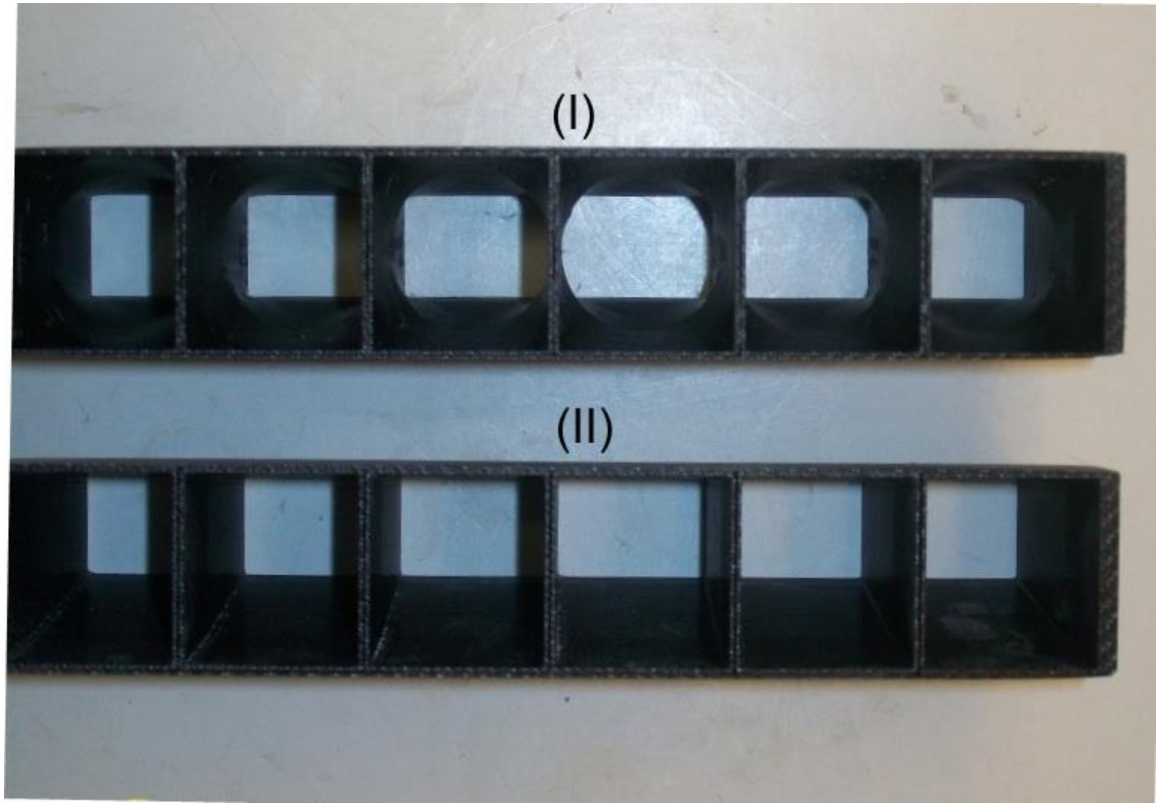
Open Jet rig (CW17)



Close-up view of nozzle and HW

- Up to about 70 psig allowed
- Microphones overhead
- 8:1 rectangular nozzle
  (5.34" x 0.66“; D=2.12")
- Inserts made by 3-D printing

Experimental Facility (inserts)



Internal geometry
Top: 'Fsh3' has rectangular-circular-rectangular passage
Bottom: '6Rec' has rectangular passage throughout

-Many other septa geometries are examined for maximum noise reduction

Septa Insert Notations

Notation	Description
Fsh3	Septa TE flush with nozzle exit (rect-circ-rect passage)
Fsh0	Duplicate of Fsh3
Insd	Septa TE stops 0.25" upstream of exit
OutF	Full-width TE protrudes out by 0.175"
Sclp	Semi-circular cut-out (scallop) at septa TE
6Rec	Same as Fsh0 or Fsh3 except rectangular passage
Dsn5–10	Same as Fsh0 or Fsh3 except passages are non-uniform

Fsh3

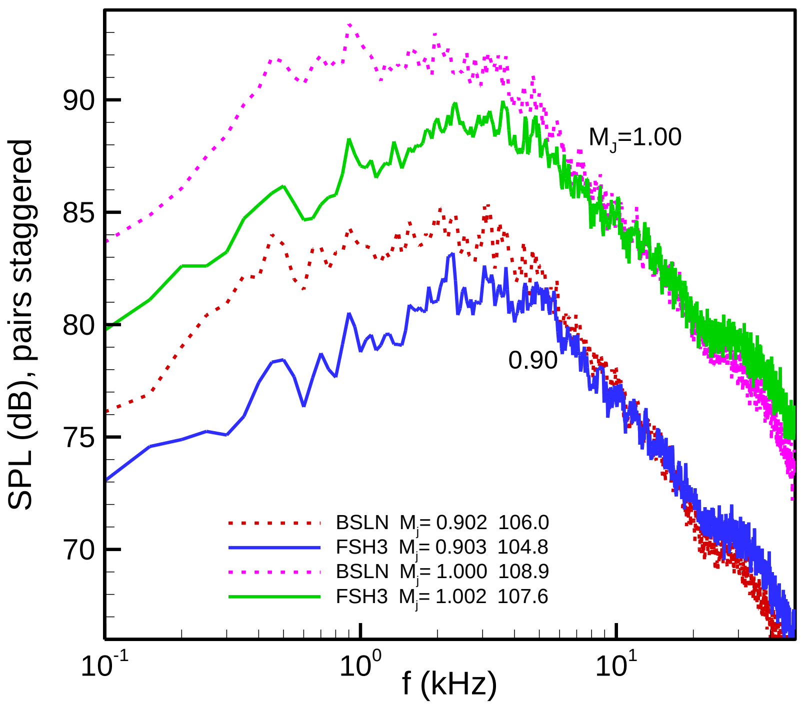
Insd

OutF

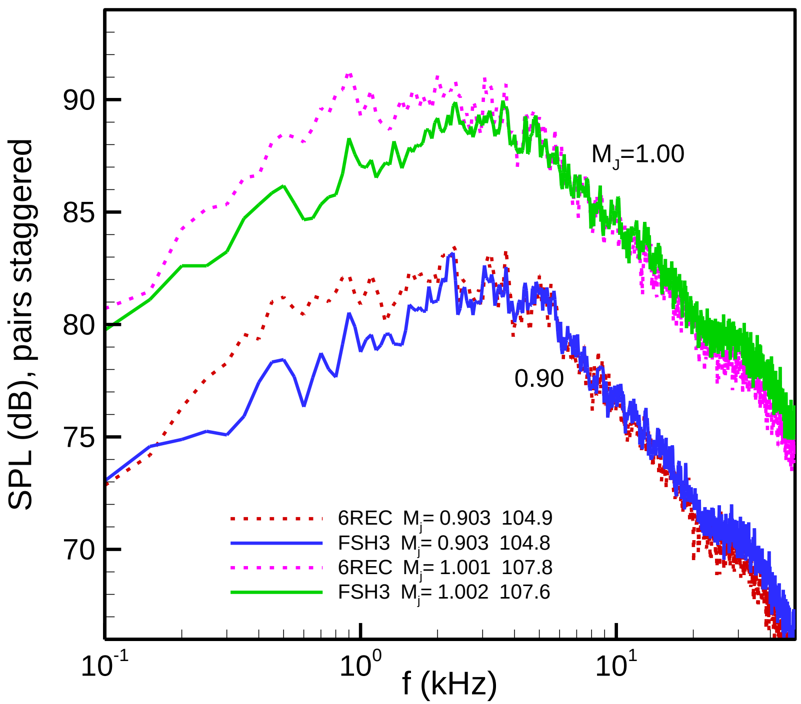
SPL Spectra comparison at two jet Mach numbers

θ = 90°; mic on broadside of nozzle

Fsh3 vs Bsln



6Rec vs Fsh3

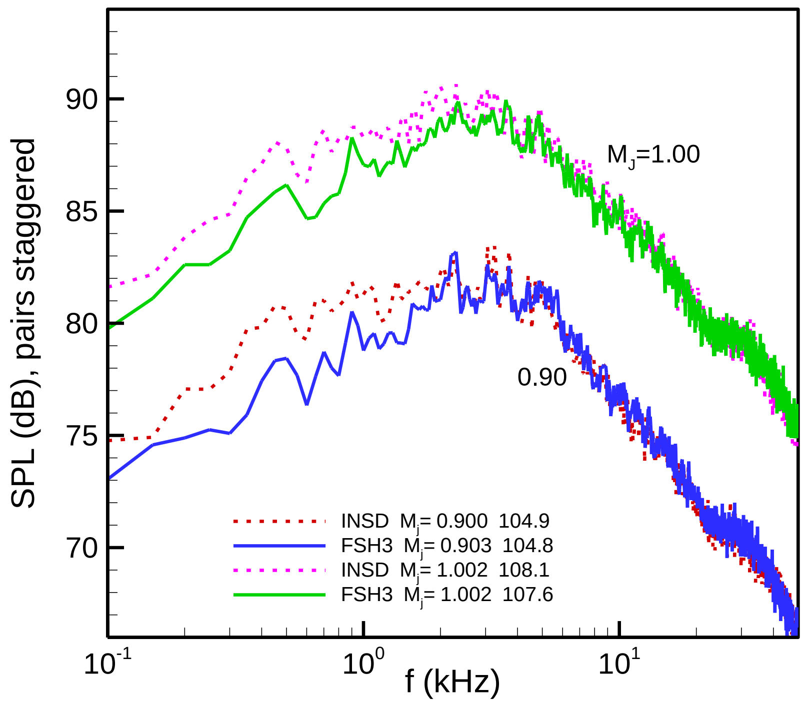


Lower noise on low frequency end for the Flsh case. Not accounted for by exit area reduction (11% smaller *D* => 1.3 dB)

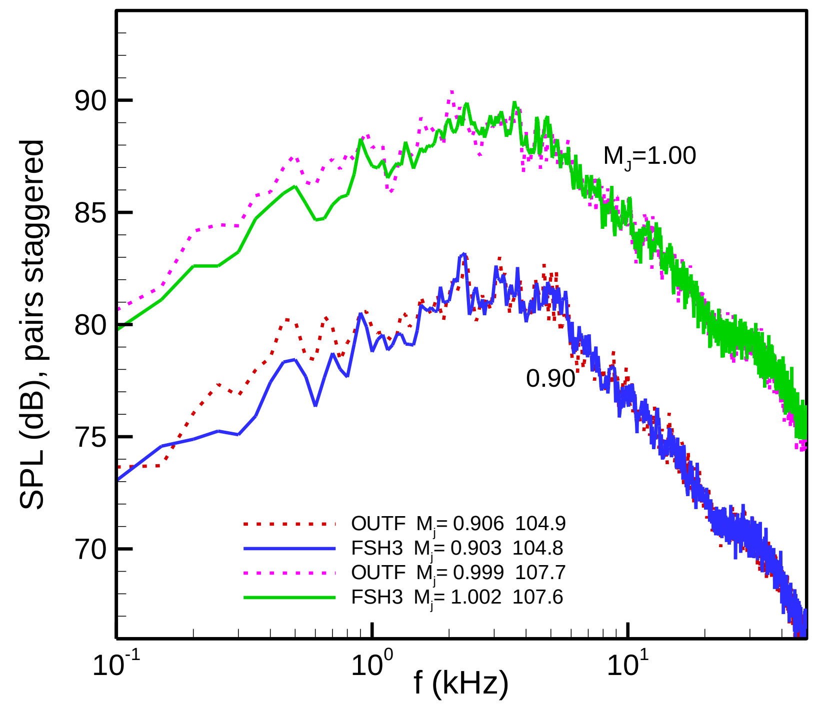
Noise reduction with 6Rec case not as much

SPL Spectra comparison at two M_j

Fsh3 vs Insd



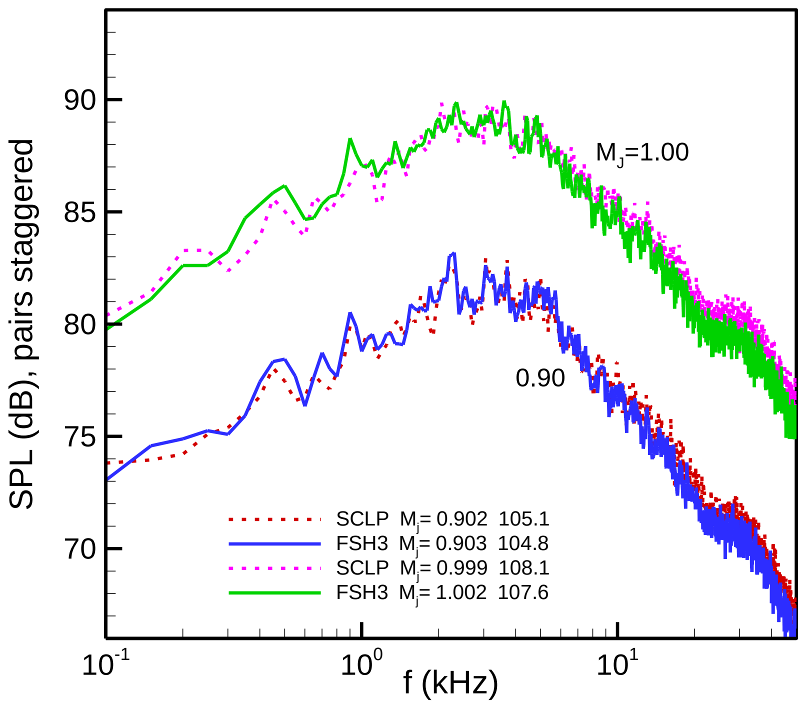
Fsh3 vs OutF



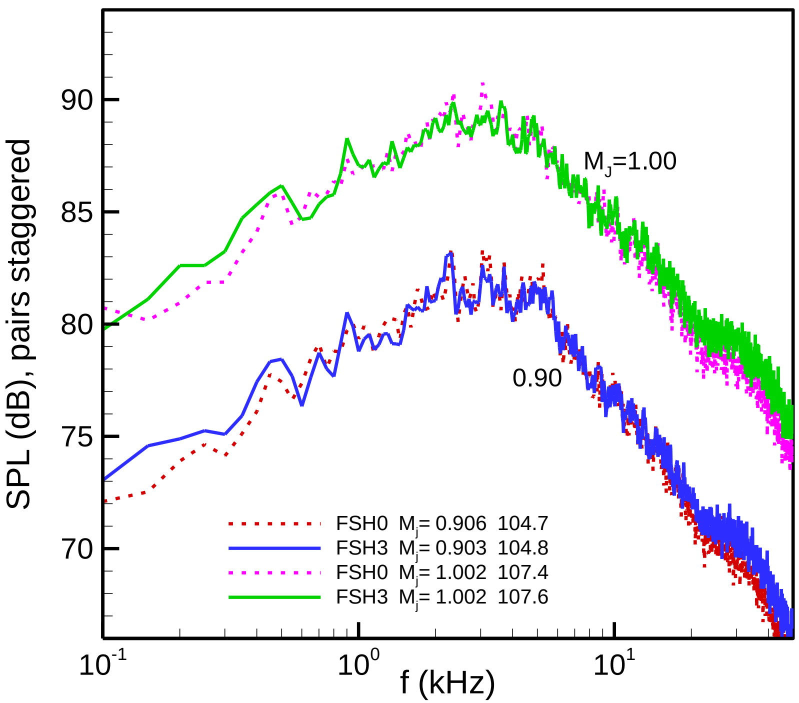
Noise reduction with Fsh3 is best so far

SPL Spectra comparison at two M_j

Fsh3 vs Sclp



Fsh3 vs Fsh0

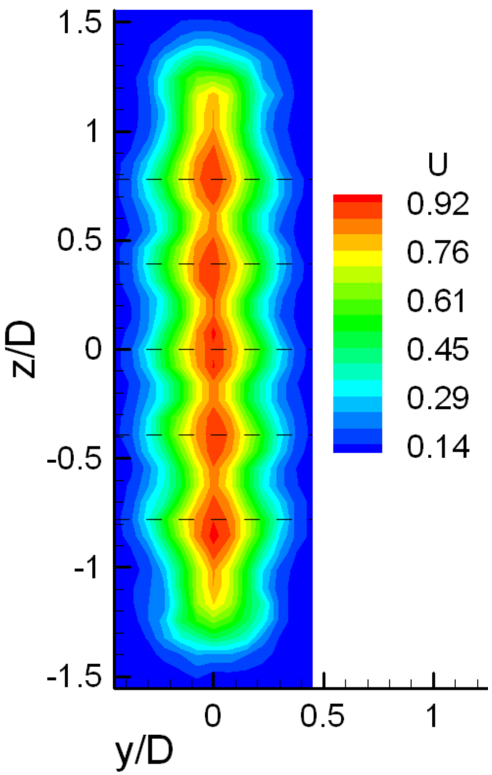


Noise reduction with Sclp and Fsh0 about same as that with Fsh3

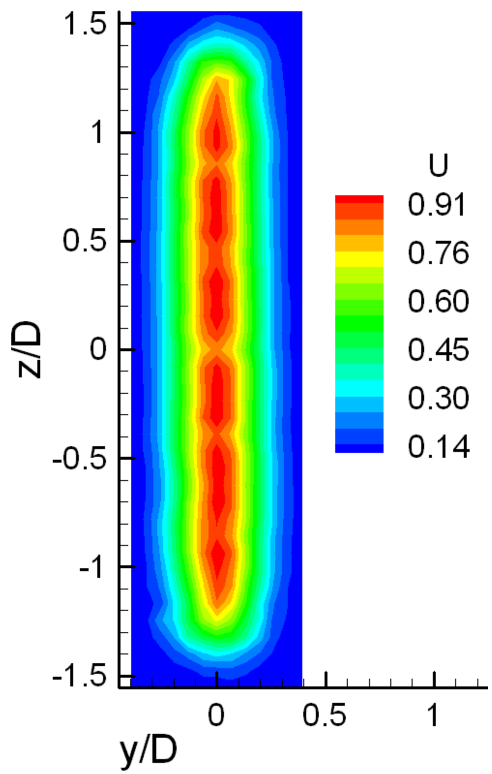
U contours at x/D=2; M_j =0.265

Hot-wire data
Fsh3: rectangular-circular-rectangular passage
6Rec: rectangular passage thru

Flsh3

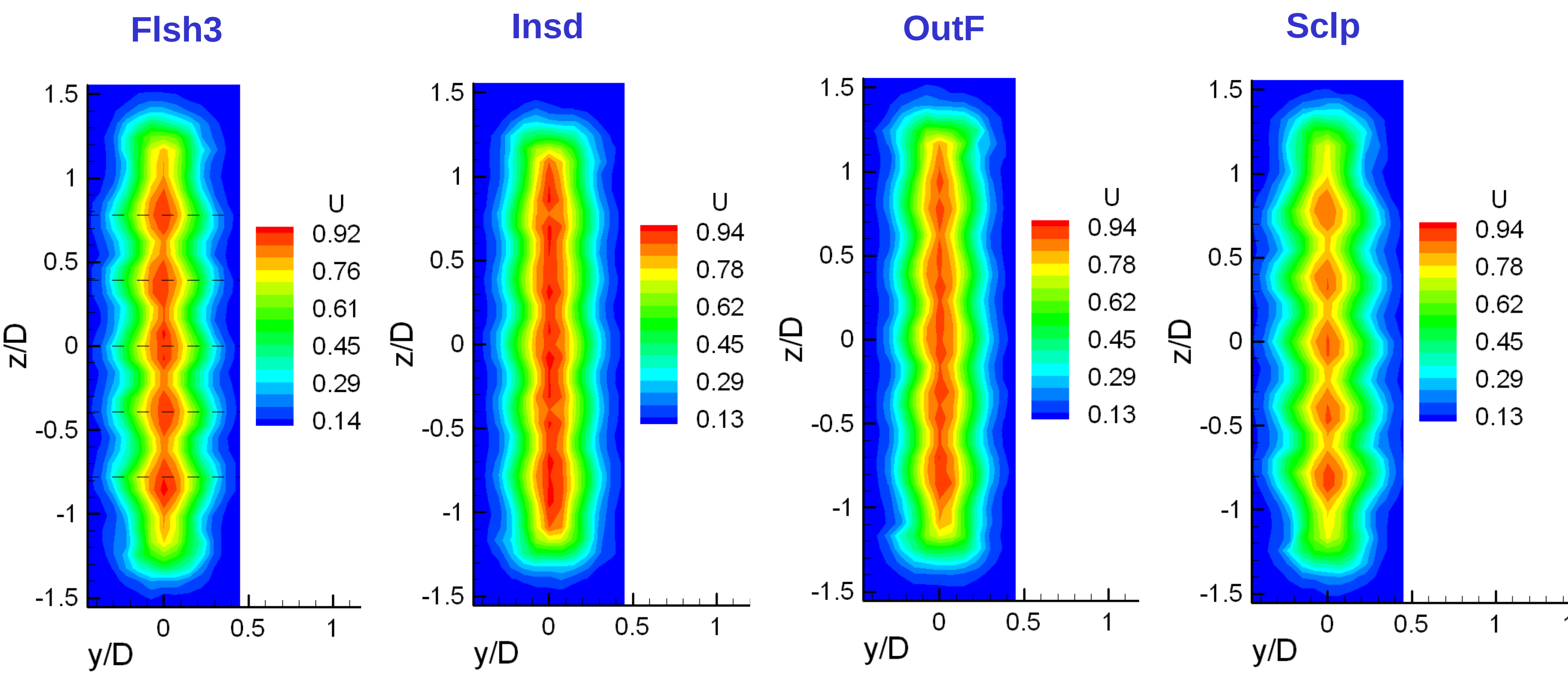


6Rec



Note only 5 cells for Fsh3 case but 6 cells still discernible for 6Rec case

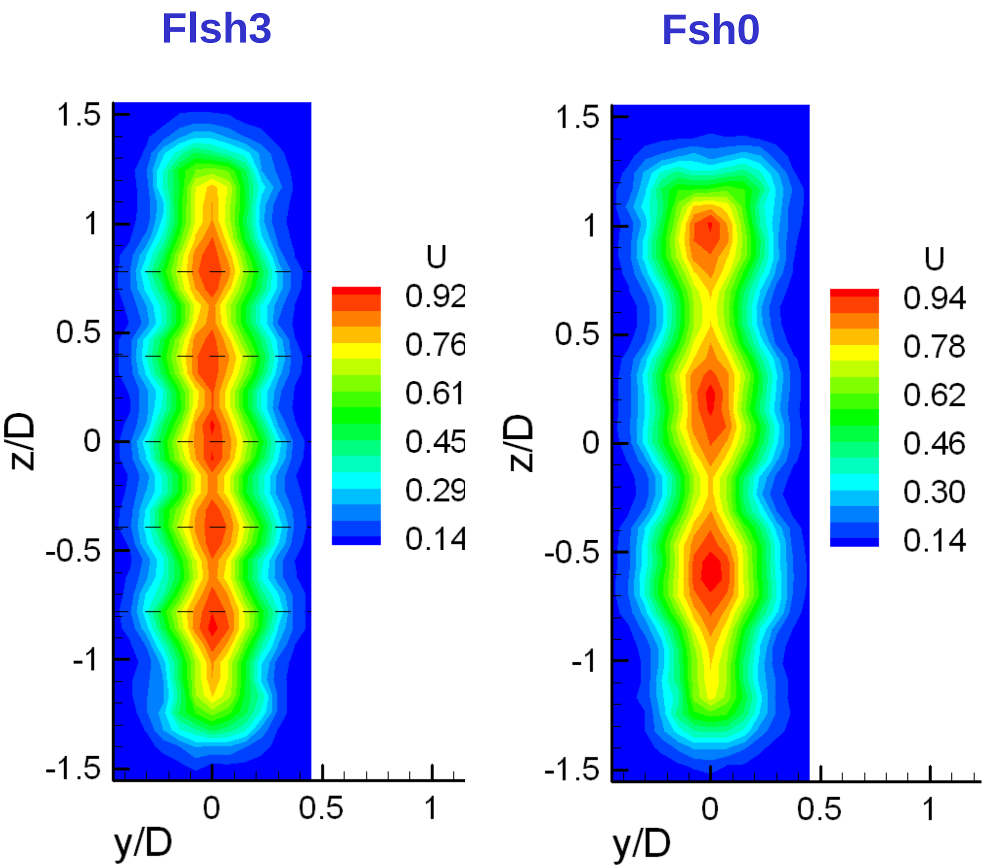
U contours at x/D=2; M_j =0.265



Similar patterns

U contours at x/D=2; M_j =0.265

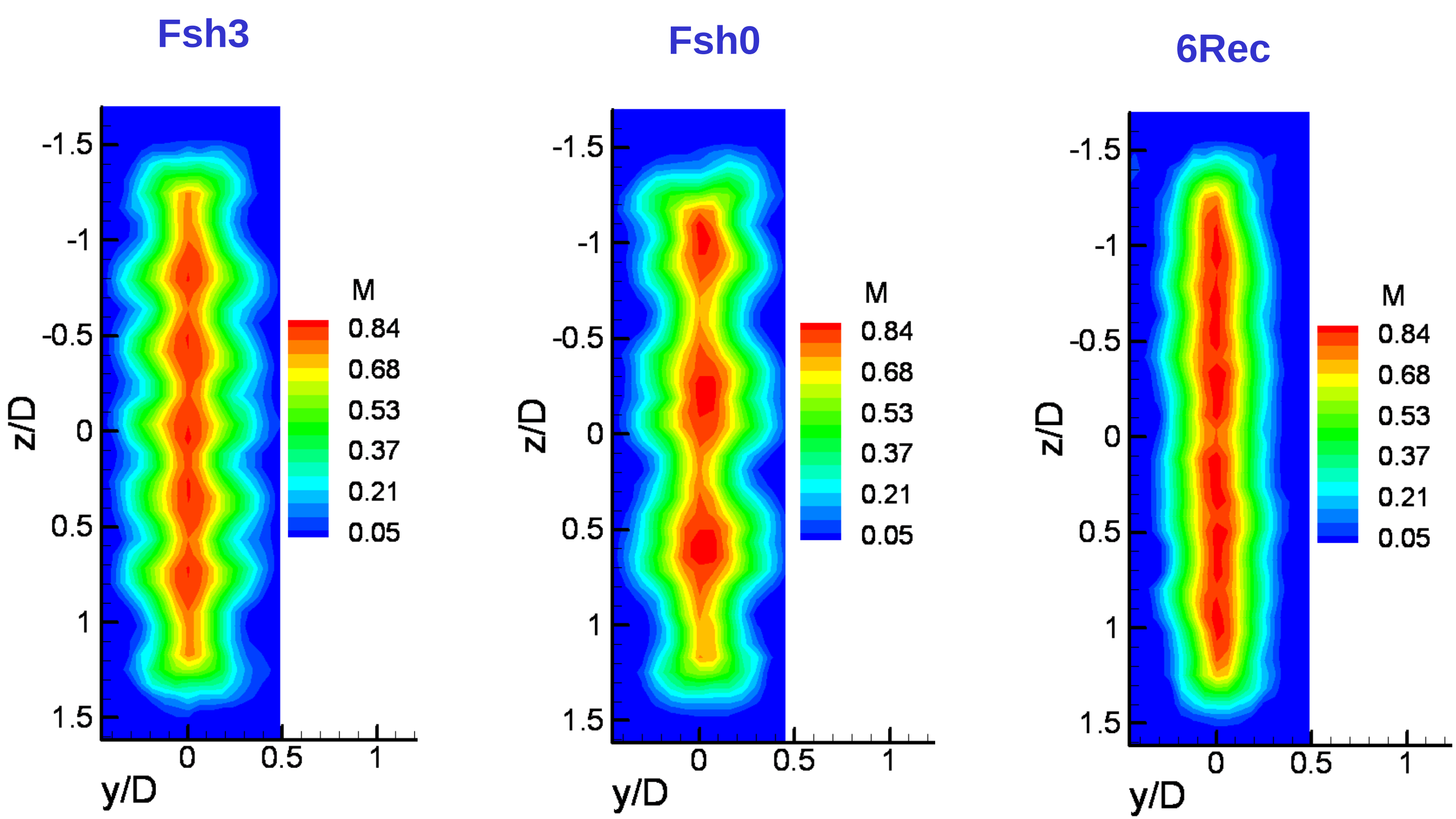
Fsh3 and Fsh0 are supposed to be identical



There is pairing activity with Fsh0 leading to asymmetric flow

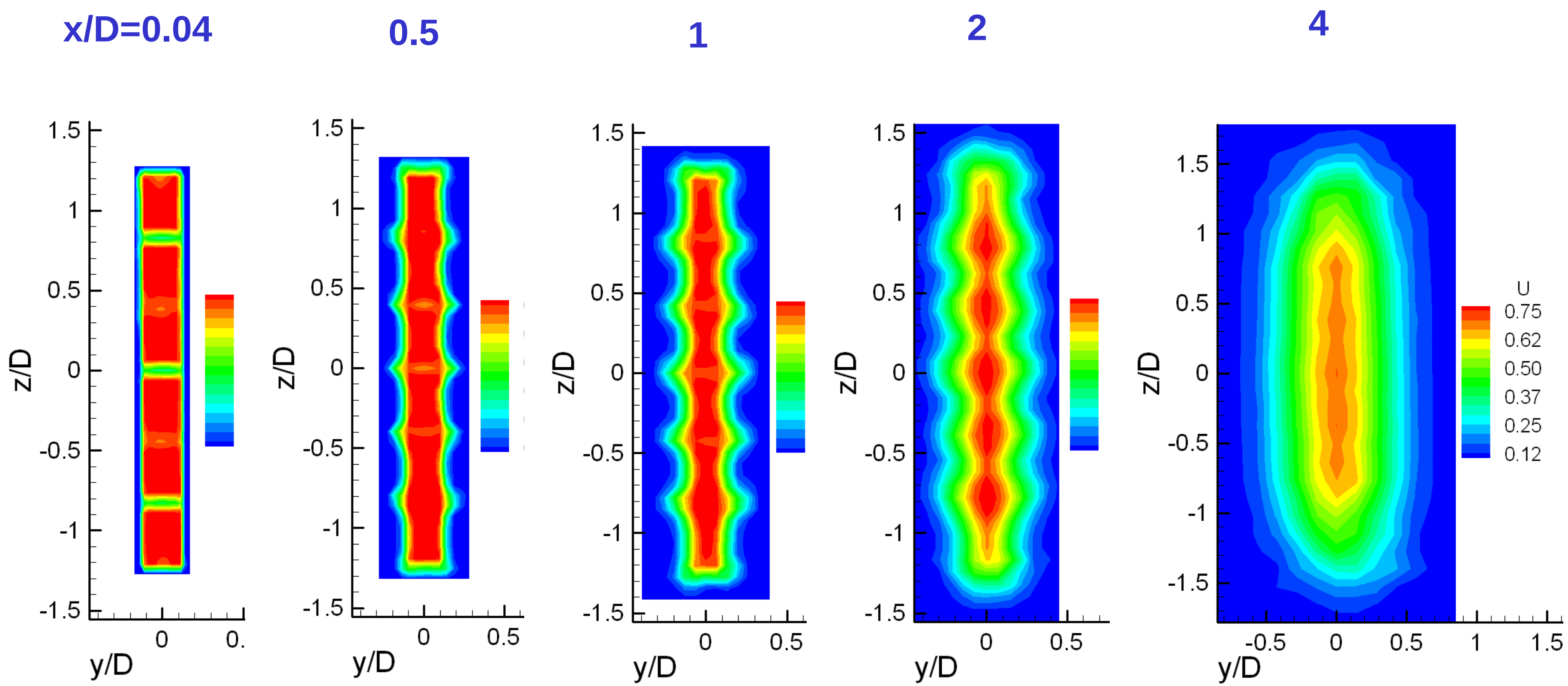
U contours at x/D=2; M_j =0.90

Pitot surveys



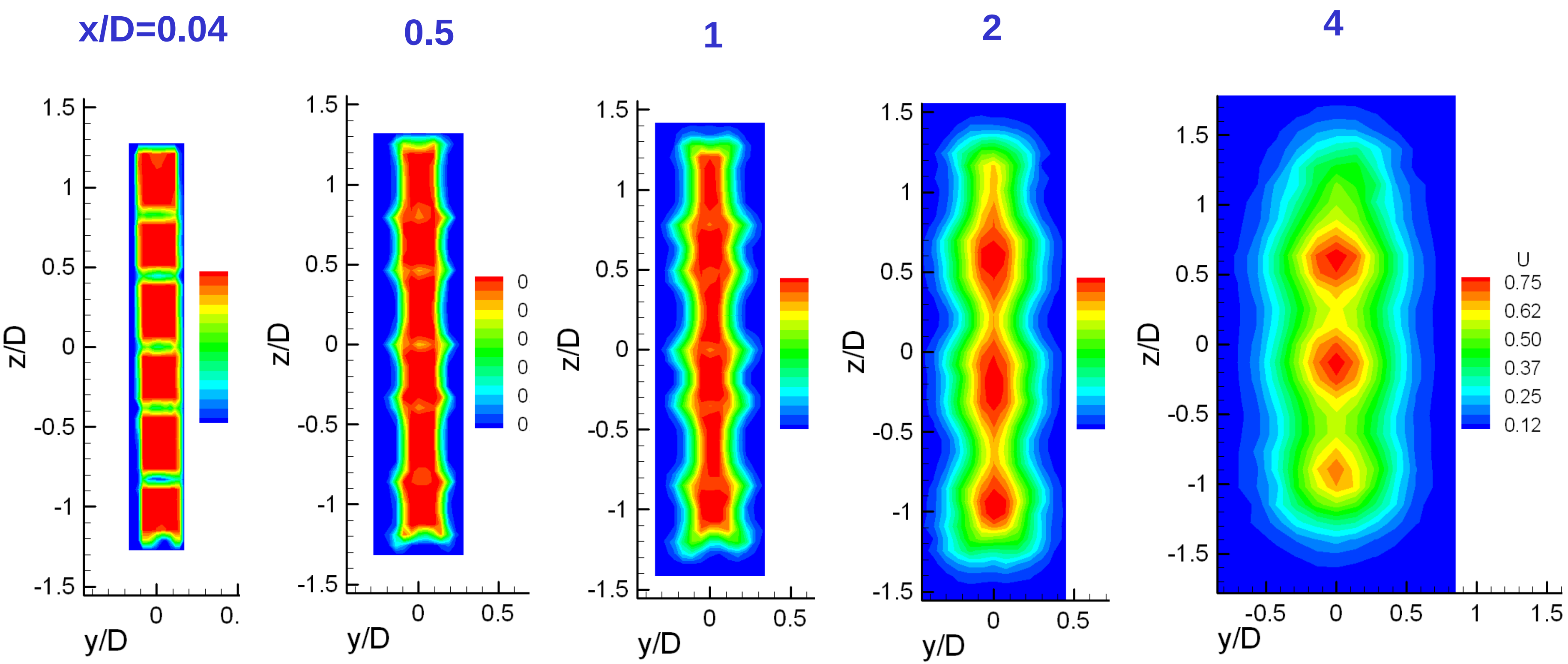
The flow patterns are the same (independent of compressibility effect)

Flow evolution Fsh3 case; M_j =0.265



Streamwise vortex pairs at ends of each of 5 septa (partitions) causes the observed pattern

Flow evolution Fsh0 case; M_j =0.265

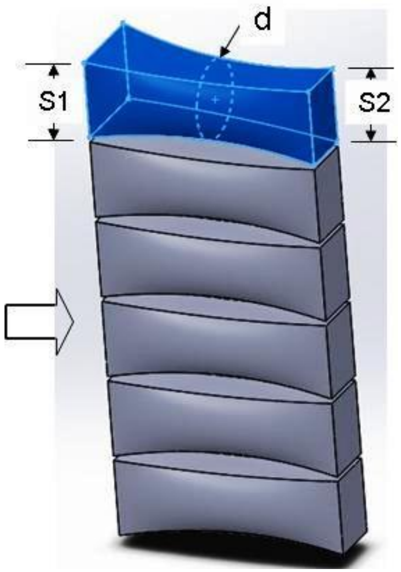


There is further interaction among Streamwise vortices

Difference in dimensions of Fsh3 and Fsh0 cases

Optical method using 'Smartscope'

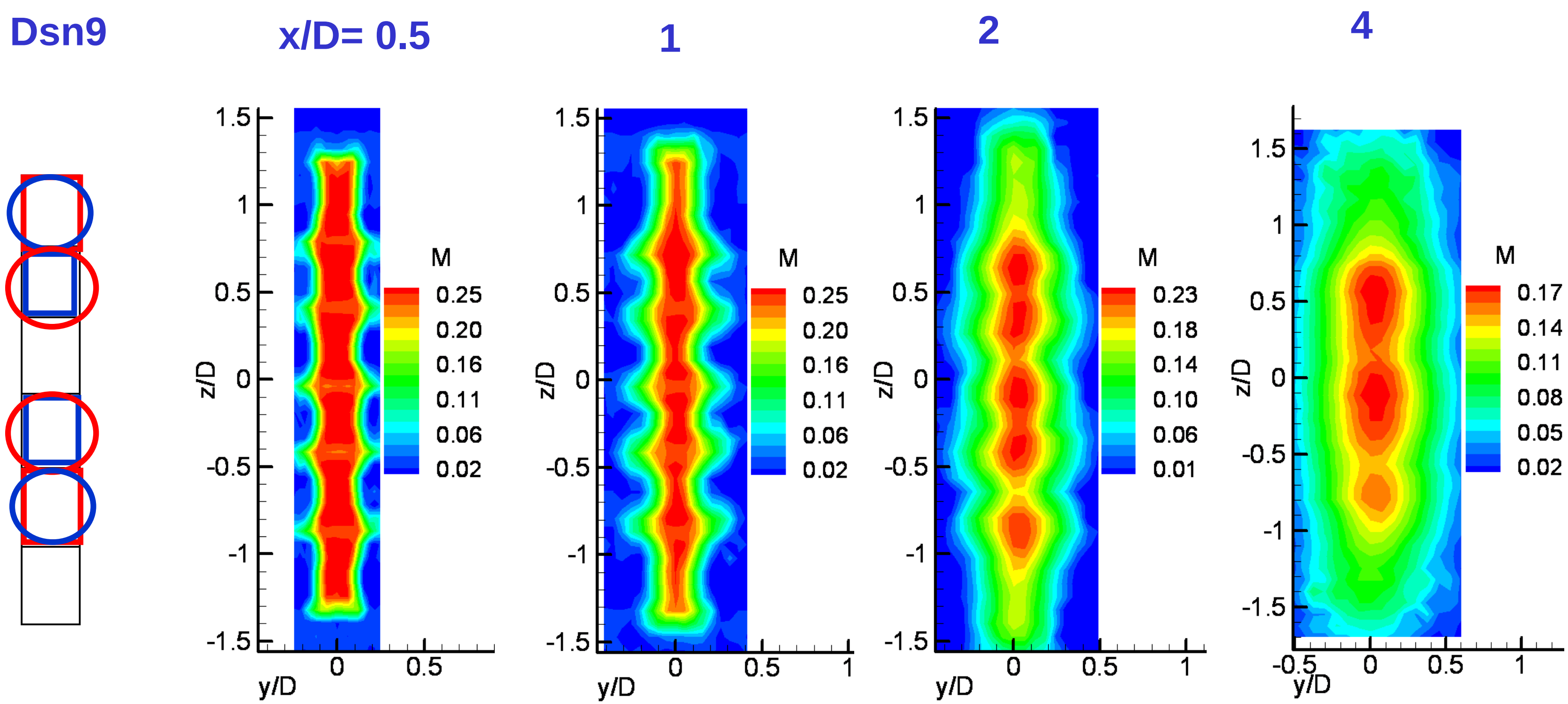
Passage	*S1*		*S2*		*d*	
	Fsh0	Fsh3	Fsh0	Fsh3	Fsh0	Fsh3
1	0.866	0.862	0.817	0.828	0.855	0.854
2	0.858	0.877	0.828	0.828	0.855	0.853
3	0.866	0.842	0.829	0.827	0.855	0.854
4	0.874	0.873	0.829	0.828	0.855	0.855
5	0.863	0.843	0.815	0.827	0.856	0.854
6	0.872	0.879	0.829	0.827	0.854	0.853



(#3) 2.8% max difference
Not much help in pinpointing cause of the difference in flow

Flow evolution Dsn9 case; M_j =0.265

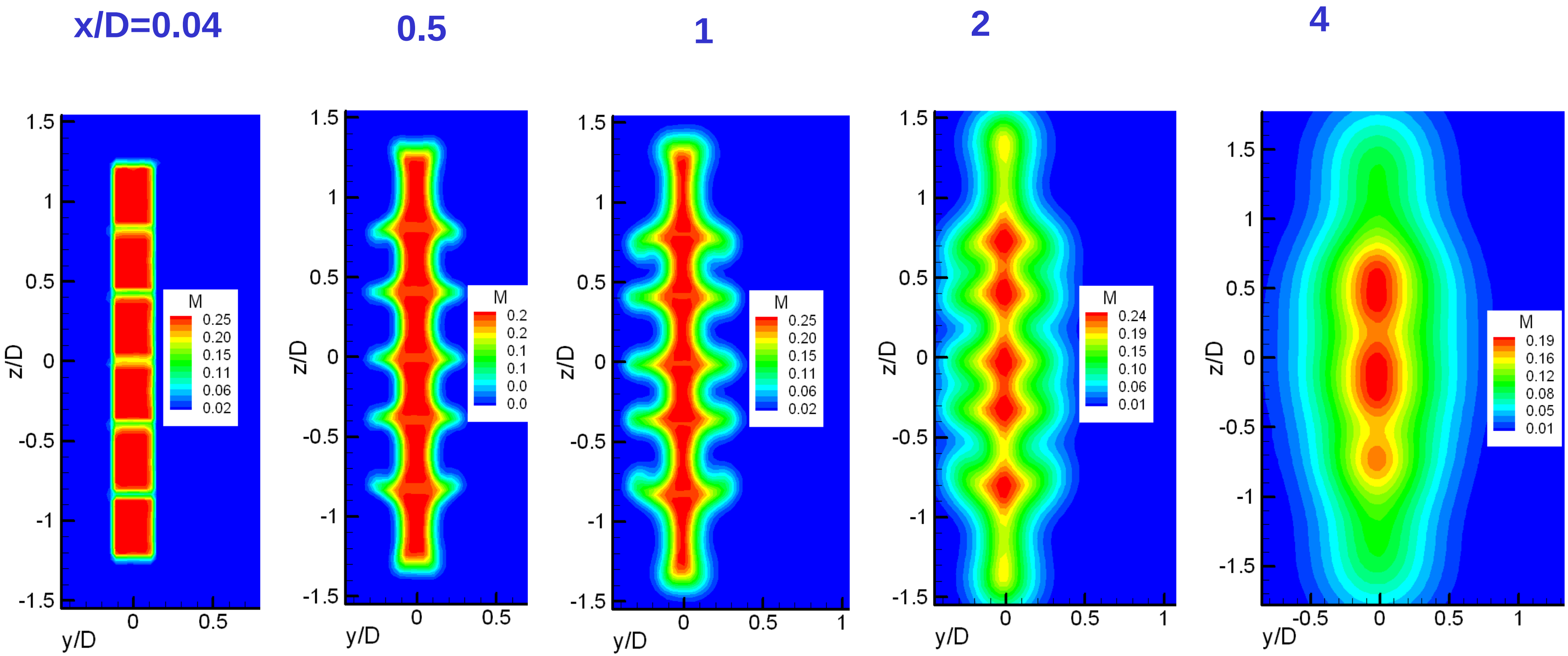
Width at exit (S2) and diameter (d) varied



Flow field similar to Fsh0 case was finally realized

CFD mean flow evolution Dsn9 case; M_j =0.27

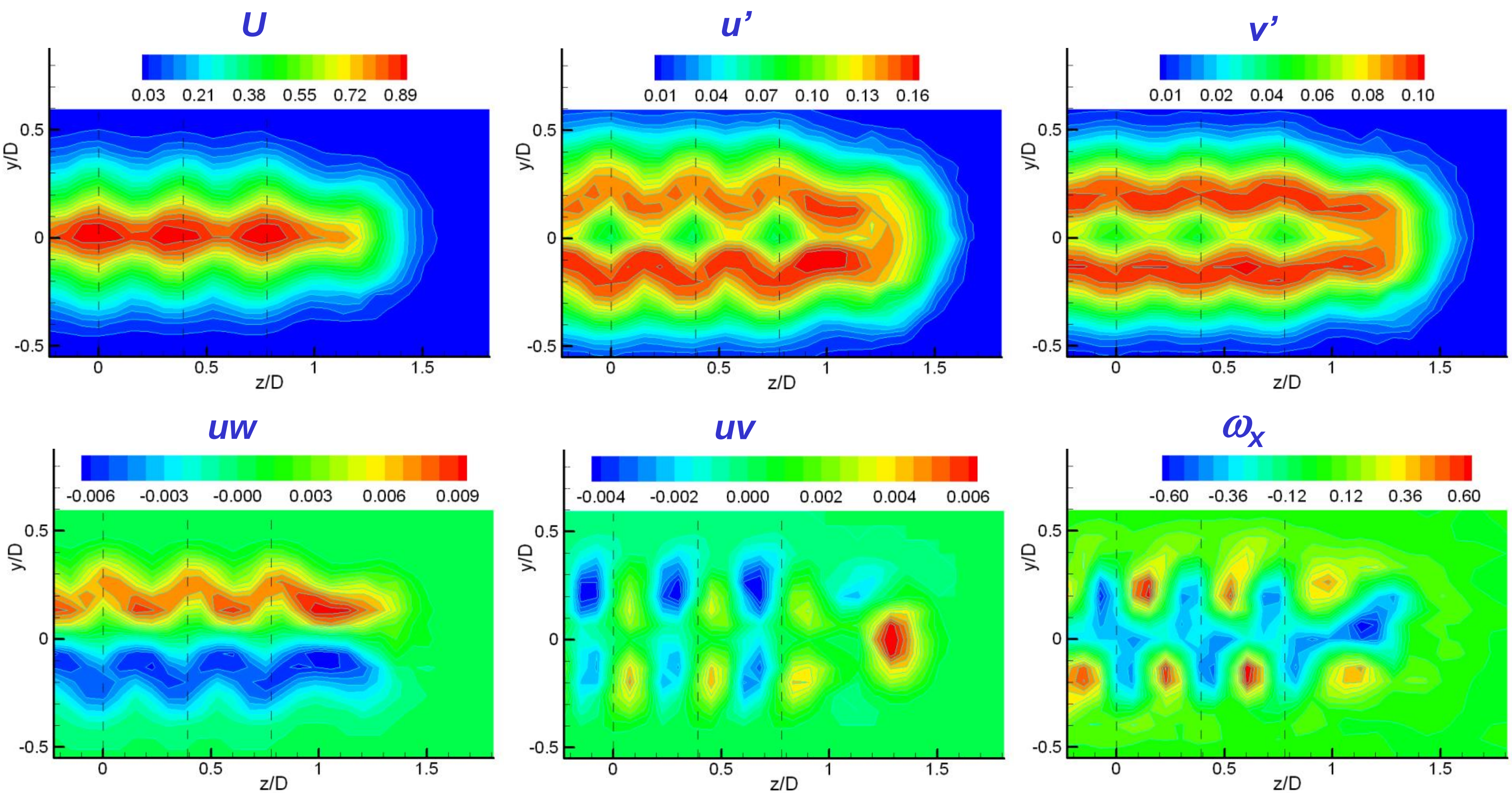
(CFD package with Solidworks)



Similar flow fields as in the experiment
(also good agreement for Fsh3 case)

Detailed flow field for Fsh3 at x/D=2; M_j =0.265

Two X-wire measurements



u’ larger than v’ (or w’). Streamwise vortex pairs at ends of septa.

Conclusions

Nozzle with septa is quieter than corresponding baseline nozzle.

Apparently, noise reduction occurs due to introduction of streamwise vortices in the flow. These vortices are produced by secondary flow within the septa passages.

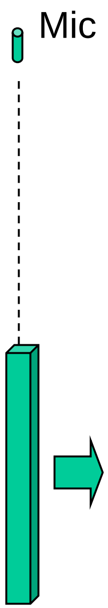
For the flush case, six cellular flow structures readjusts to produce five regions of high-speed flow by the action of ω_x-pairs.

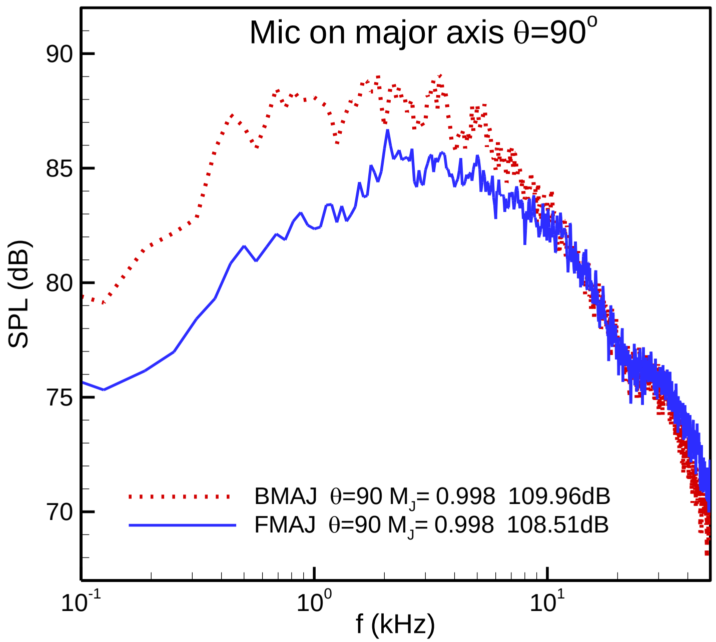
Small difference in fabrication of the flush case causes vortex pairing activity leading to an asymmetric flow structure.

By intentionally varying the dimensions of the flush case the latter flowfield could be reproduced.

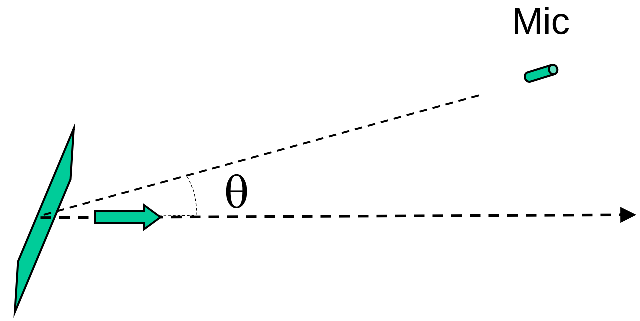
Lesson: the streamwise vortices and hence the flow and noise from the jet are quite sensitive to the septa geometry.

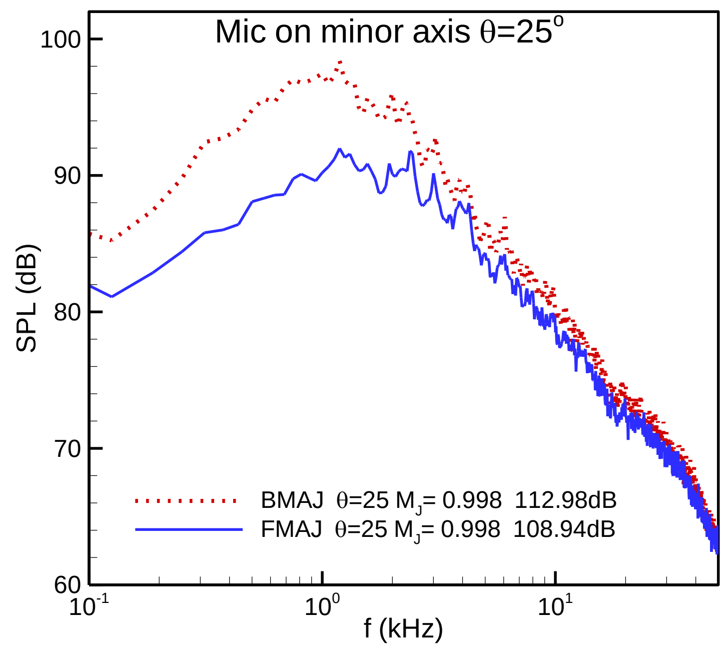
SPL Spectra Flsh vs Baseline at other angular locations; M_j=1





Narrow side (ϕ=90°); θ=90°



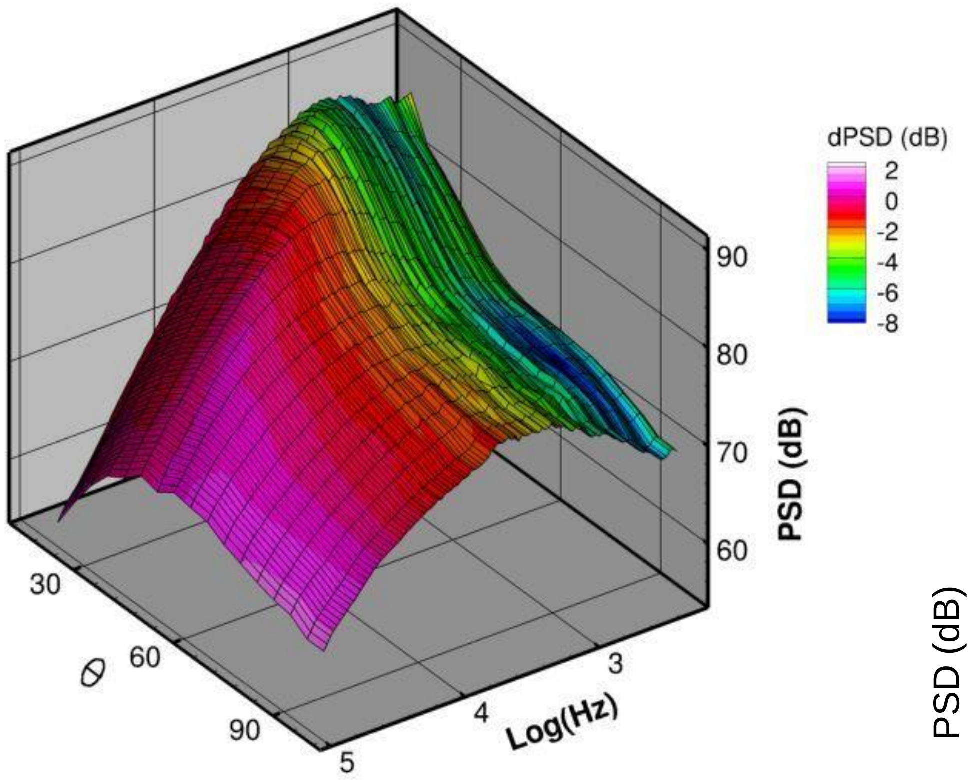


Broad side (ϕ=0°); θ=25°

Flsh case exhibit similar noise reduction at other azimuthal (ϕ) and polar (θ) locations

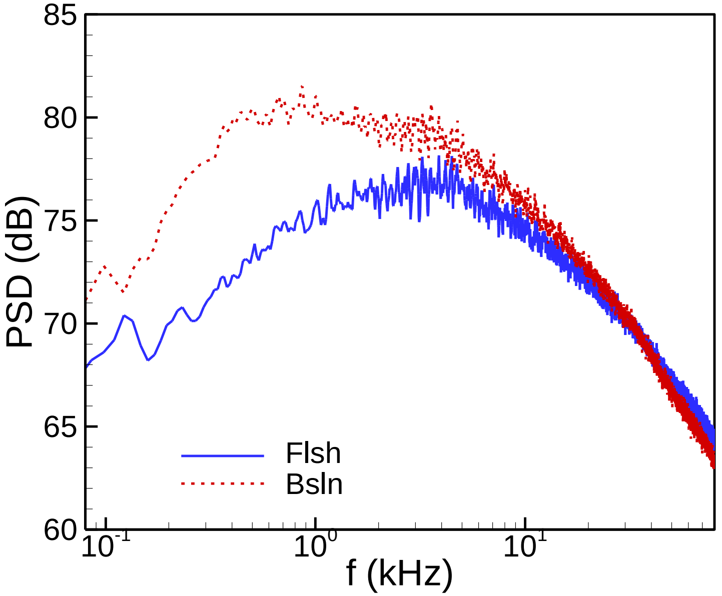
SPL Spectra data measured in the AAPL

Flsh vs. Baseline cases; M_j=0.99



Carpet plot of PSD
Broad side (ϕ=0°)
24 θ locations

Observation in CW17 is confirmed by accurate data taken in the AAPL



Direct comparison at ϕ=0°, θ=90°